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China Report

SCIENCE AND TECHNOLOGY

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CHINA REPORT

SCIENCE AND TECHNOLOGY

CONTENTS

PEOPLE'S REPUBLIC OF CHINA

ABSTRACTS

NEW ORIENTATION, GOAL OF MILITARY ENTERPRISE S&T WORK DISCUSSED

Beijing KEYAN GUANLI [SCIENCE RESEARCH MANAGEMENT] in Chinese No 2, Apr 84 pp 47-49

[Article by Yang Defu [2799 1795 1381] of the Xindu Machinery Plant in Chengdu: "Orientation and Goal of S&T Work in Military Enterprises After Their Change of Management Methods"]

[Text] The change of enterprises from production management methods to administrative ones is an inevitable trend in national economic development, an inevitable result of their constructive and comprehensive management reorganization, and also a major indication of their development towards high standards.

Military enterprises are a major component of socialist enterprises. It is also inevitable that they are faced with the problem of a change of management methods. Great changes have occurred in their production and product mix in recent years through reorganization and reform. They have changed from a single military product mix to a jointly developed military and civilian product production structure, and thus from a simple production viewpoint in the field of production alone to an administrative viewpoint in the field of circulation. Changes have occurred in the guiding ideology of running enterprises, and particularly that products suited to satisfying the needs of marketing must be developed in the production of civilian products. Since the socialist economy is still a commodity economy, the market thus still maintains a definite regulatory role in social production. Competition exists, and we must have the good things of our own unique style and an answer to what people need and request in order to obtain a market. How can this kind of product be developed? We must have the ability to stably support ourselves in the forest of enterprises through competition and to rely on technical progress. We must therefore explore the orientation and goal of developing and popularizing new technology in military enterprise scientific research after their change of method, and this article intends to discuss several views on this problem.

1. Stress Technical Breakthroughs and Achievement Transformation

Stemming from the needs of national defense in the 1950's, a group of military enterprises were established. This group of enterprises has contributed to national defense in the past 30 years. Through production practice and technical transformation all their technical forces have become fairly solid. Although they have definite gaps compared to similar foreign industries, yet they are not all backward. Along with product modification, the enterprises themselves have continuously transformed and developed and are being perfected. This group of old enterprises is generally concentrated in qualified personnel, knowledge and technology, and is matched and coordinated professionally. They have sound methods in modern calculation, analysis, inspection and measurement, and advanced special equipment. They have a fairly strong comprehensive technical capability, stable technical policies, and a rather high technical quality. They can make breakthroughs in highly difficult technical problems, and particularly in key scientific research problems which the state has called on them to tackle.

Taking our plant as an example, the Chinese Mechanical Engineering Institute pointed out in 1979 that our country is still rather backward in "microdisplacement technology", and that we can be on a level with world standards if we can overcome the 0.1 micron level. Our plant has been fairly careful of this call, neither blindly developing nor lightly regarding it. Based on a feasibility analysis, we have weighed the plant's actual strength and have made the strategic decision to consider that all projects which can win honor for the state and the nation and raise confidence in the creative power of the Chinese nation, even if they temporarily don't demand this kind of high precision for this enterprise in production, scientific research and technical transformation and even if they temporarily cannot be of benefit to this enterprise in economic results, should be considered according to their social results. We have thus not only organized our forces to design uniquely conceived, new, and original microdisplacement equipment, but have also manufactured 0.05 micron level microdisplacement equipment. Through trial and perfection, we have now basically achieved marketability, have rapidly transferred it to different trades and fields, have signed many contracts, and have played a key role in the electronics industry, machine tool manufacture and the spaceflight industry as well as in higher institutes and PLA units, and particularly in the manufacture of extra large-scale integrated circuits for the electronics industry. The plant has also achieved rather good economic results.

After a change of management methods in a 100 million yuan investment military enterprise, the goal pursued by the enterprise should be comprehensive results. It should not only pay attention to improving its economic results, but also to improving its technical quality. Stressing the year's economic results is one aspect, but even more attention must be paid to long-term, sustained, stable, and comprehensive results. A great military factory with an abundance of capable people, strong work forces, numerous disciplines, sound measures and qualified specialists should develop its strong points and play a major role, and should not only consider a few present economic results and carry out certain minor undertakings. A large and complete key

enterprise completed during the early period should develop its potentials as a large and complete enterprise. If it only makes certain cooking and dining utensils such as knives, spoons and spatulas and certain minor commodities, although it can temporarily achieve certain economic benefits for the enterprise, yet it is impermissible to overlook the social abuse it causes. Since local state-run and small collectively-owned factories socially produce these minor commodities, none of them can compete with those military enterprises which have great strength, but can only be reduced to becoming a group of factories which must be shut down, suspend operating, or switch to other business operations. But these military plants cannot produce these small commodities for long, and if the factories producing them truly suspend production and switch to other business operations, gaps will appear in market supply. From the point of view of technical economic results, large enterprises must not engage in these "inefficient" undertakings, but should concentrate their efforts on social needs and on tough projects which ordinary enterprises cannot handle.

Technical transfer must always be carried out along with technical breakthroughs, and this can accelerate the process of modernization and promote S&T progress and national economic development. The method of blocking a good S&T achievement on the excuse of safeguarding technology is undesirable. Maintaining secrecy is of course essential, but we must consider for whom we are maintaining it. We must do a good job in maintaining secrecy for everything which could damage national interests and honor; but we cannot maintain secrecy for whatever is beneficial to national development and the prosperity of the national economy. Whether technical breakthroughs can be transferred to different trades, departments and units is not a theoretical question which has not yet been understood, but is a practical problem for which we should strive to overcome ideological obstacles. Ways and means of transferring achievements include providing free support, paid transfer and technical contracts. We believe that for those small enterprises which have weak forces yet are favorable to expanding employment, we should adopt the method of "helping them to start and accompanying them" in order to support their development and expansion. We can adopt paid transfer methods for those achievements which have a fairly high investment and fairly great technical value and high economic results after the transfer. And for those achievements which are transferred to specialized production enterprises to carry out commodity production and which also have very high economic results, both sides should sign fair economic interest distribution contracts and agreements.

2. Stress the Continuing Improvement of Military Technology and its Entry and Spread into the Civilian Product Sector

Military enterprises have an important mission in national defense. The strengthening of national defense forces is an important guarantee for our successful carrying out of the four modernizations. The need to maintain the development and improvement of continued military technical excellence is a major matter not to be neglected in technical work in military enterprises after their change of management methods. According to reports, although certain large-scale foreign military enterprises have all been comprehensively developed, yet their military technology has never weakened.

This is because they have permeated excellence, development and improvement into civilian production technology. As to the characteristics of the products themselves, military products have their own particular qualtiy and requirements. The economic benefits now achieved by military enterprises in producing civilian products (particularly goods which are in great demand) are fairly high, and the factories have seen the material benefit, yet they cannot weaken the development and improvement of military production technology for this. Of special importance is that the development of quality management technology and technological base can only be further perfected, reflecting its scientific nature and improving military technology, and cannot be interrupted for even a minute.

The permeation and spread of military technology into the civilian products sector is a major advance in the comprehensive utilization of technology. It will have the effect of changing the quality of civilian industry. In a certain sense, it is also an aspect which satifies social needs. It can undoubtedly increase and expand the reproductive, innovative and development capacity of civilian industry and give the enterprises considerable appropriate storage capacity. It can always coincide with the rhythm of social needs and market changes and be highly appropriate.

It is rather difficult to clarify the precise implication of the spread and permeation of military technology into the civilian industry; the need to know what kind of specific military technology the civilian industry will accept is also similarly quite complex. Since military technology is generally multi-discipline in arms and mutually permeated and also repeatedly comprehensive, it forms a fairly complex and complete technical system. But we can conclude that using certain large-scale and broad-based practical technology (such as spray coating, case-strengthening, metering analysis and special manufacturing technologies) in civilian industry can produce rapid effectiveness and good results.

Since many military enterprises produce a certain amount of civilian products, regardless of variety standards and output, they should first spread and permeate the technologies of their own products in order to improve the functional value of civilian products. There are still certain difficulties in popularizing this kind of proliferation (also called interior proliferation). This is because many years of single military product production has formed a set of traditional, special technical management practices. In order to make technology brisk but not disordered, and managed but not to death, we must still make certain method changes.

The proliferation and permeation of military technology into socially needed civilian industry can be called "external proliferation and permeation", and belongs to the category of technical transference. But external proliferation and permeation, enabling the receiving side to achieve the basis to succeed, should be "systematic proliferation" achieved by the receiving side on its own initiative. This point is of extreme importance. The so-called "systematic proliferation" refers to the transferring side giving assistance and introduction to the receiving side in technical matters

related to their technical needs. For instance, in spray coating technology, the receiving side can select what will become the major contradiction for technological parameters in spray-coating technology; the transferring side cannot thus alone satisfy this need, but should introduce the technological matters related to parameter selection; all experiences, such as spray coating materials, equipment readjustment and pre-spraying handling, as well as analysis and elimination of defects, should be explained. Only in this way can the receiving side acquire genuine technology at a fair price and a guarantee of reliable technology. Taking another example, in transferring the principle of cutting parameter selection for materials which are difficult to process, it is necessary to explain the selection of cutting tool materials as well as the necessity of cooling methods and the matched selection of cooling lubrication fluids, and even the condition of processed materials; and complete technical support can only be formed in this way.

3. Stress Storage Technology, Promote the Technical Transformation of Enterprise Intension, and Improve Enterprise Quality

Factories must be modernized and have a highly developed productive force, and we must carry out technical transformation of old military enterprises in order to improve their technical quality. Upgrading and development of technologies are thus outstanding problems which must be solved.

Based on the present situation in enterprise technology, we should be realistic; do what we are capable of, and develop three technical types. We must first develop according to our strength "appropriate technology" for practical technical problems which can be solved in large-scale and broad-based production; second, this enterprise's original and outstanding technology is the most dynamic factor in the factory's technical transformation, it can most highly reflect the factory's S&T standards and potential, and must be vigorously propped up and developed; and third, in order to ensure the continuity of scientific research on product development in enterprise production, we must strive to develop the storage of new techniques, technology, materials and equipment. This will enable the enterprise to regularly improve its quality and to maintain its leading position.

12267
CSO: 4008/274

JIANGSU HOLDS DEFENSE SCIENCE, TECHNOLOGY TRADE FAIR

OW240130 Nanjing XINHUA RIBAO in Chinese 15 Jun 84 p 1

[Excerpts] The provincial Trade Fair for the Exchange of National Defense Science and Technology opened at the Servicemen's Club in Nanjing on 14 June. On display were more than 1,200 new products, technologies and techniques of 62 defense-related enterprises and establishments from Nanjing, Wuxi, Suzhou, Changzhou, Zhenjiang and Yangzhou cities. These units are ready to provide these new products and techniques as well as technical advice and service to civilian enterprises and establishments. Some 400 new products, technologies and techniques can be transferred to local enterprises and establishments. The defense-related units will also engage in joint production with local enterprises and establishments in order to support civilian industrial departments in transforming and promoting their technologies.

Responsible comrades of the provincial people's government and its departments, commission, offices and bureaus as well as thousands of responsible comrades and technical cadres of enterprises and establishments from all parts of the province attended the trade fair.

Enterprises and establishments in science, technology and industry for national defense in our province have a powerful technical force and many of their new technologies and products are of rather high standards at home and abroad. At a recent meeting on this subject, the provincial government repeatedly stressed the necessity to adopt important measures to speed up the transfer of defense-related technology to civilian quarters so as to promote technological advance in our province. It was under this ideological guideline that the provincial commission on planned economy and the provincial commission in charge of science, technology and industry for national defense jointly held this trade fair.

On display at the trade fair were the latest achievements that have emerged from the new technological revolution of our time.

Defense-related enterprises and establishments also displayed new products and technologies used to conserve energy, promote transportation and protect the environment.

CSO: 4008/344

WUHAN STARTS FIXED TERMS FOR SCIENTIFIC CADRES

HK200503 Beijing GUANGMING RIBAO in Chinese 6 Jun 84 p 1

[Report by Ding Bingchang [0002 3521 2490]: "Intermediate-Level Cadres of Wuhan City Scientific and Technological Committee Serve for a Term of 3 Years"]

[Text] Recently the 13 intermediate-level cadres in the Wuhan City Scientific and Technological Committee, who are the first batch of cadres employed under a system of a fixed term of employment, formally took up their official posts. The leading party group of the committee clearly announced: The term of the employment for this batch of cadres is 3 years. At the end of this term, these cadres will be assessed by the masses of the people and the organization. Those who have proved to be competent can be reappointed to their posts with the approval of the upper level and those who have proved to be incompetent will be transfered to other posts.

This batch of cadres was employed after the organization assessed them on the basis of voting by the masses of the people and after it reported the matter to the city organization department for approval. Only 4 of the 13 cadres are cadres reappointed to their old posts, while the other 9 are all newly appointed to these posts. Originally, there were no qualified scientific and technological workers among the intermediate-level cadres at the committee, but now six of the nine newly appointed cadres are engineers and one of them is an assistant agronomist. On average, these 13 cadres are 7.7 years younger than their predecessors.

During the term in office of these cadres, they will have their official positions, powers, and duties within the scope stipulated by the job responsibility system. Every year, the masses of the people and the relevant department will assess their thoughts, morality, management ability, work attitude, and contribution and the results of the assessment will be recorded and filed as the basis for their reappointment and promotion.

Engineer Mao Jinwen who is appointed director of the planning office expressed the following view: We do not want to become "officials," but since the masses of the people have confidence in us and have put us in these posts, we should do our work well. Otherwise we will fail to live up to the expectation of the people. Though it has been less than half a month since they took up their posts, they have all entered into the spirit of the "characters" they play and begun to take charge of their work.

CSO: 4008/340

NATIONAL DEVELOPMENTS

BRIEFS

BUDAPEST SCIENCE MEETING--Budapest, 2 July (XINHUA)--A general meeting of the 9th International Federation of Automatic Control (IFAC) opened here today with more than 1,000 scientists from over 40 countries attending. A 31-member Chinese delegation led by Song Jian, director of the board of directors of the automatic society, is attending the meeting. IFAC, set up in 1953, is one of the biggest and most influential international academic organizations in the field of automatic science and technology. China is one of the founder nations. IFAC is aimed at giving an impetus to the development of automatic science and technology in the engineering, social, economic and biological fields. More than 600 academic papers will be read out at the 5-day meeting, 34 of them by Chinese scientists. IFAC has 41 member states and holds a general meeting every 3 years. [Text] [OW030759 Beijing XINHUA in English 0713 GMT 3 Jul 84]

GUANGDONG ARTIFICIAL PROTEIN FACTORY--Beijing, 4 July (XINHUA)--An artificial protein factory is to go up in Jiangmen in Guangdong Province's Pearl River delta, according to the state science and technology commission. It will be the first large concern in China to use biological engineering and is expected to turn out 10,000 tons a year when it goes into production in late 1986. It will make single-celled protein from yeasts, bacteria and other micro-organisms cultivated with molasses and ammonium sulfate. The product will be used as a feed additive speeding growth and improving resistance to disease. The delta is China's largest sugar producer and produces one fifth of the nation's molasses. This is expected to increase. According to the commission, in 1982 Chinese ate only 6.9 percent of their protein in the form of animal protein, as against some 30 percent in developed countries. With rising incomes, this has increased by 15 percent a year. The factory will use air-lift fermentation tanks operating continuously under microcomputer control and have an advanced research laboratory. [Text] [OW040912 Beijing XINHUA in English 0759 GMT 4 Jul 84]

HUBEI SCIENCE, TECHNOLOGY CONFERENCE--The first Central-South China conference on a scientific and technological service and cooperation network concluded in Hankou this afternoon. Attending the conference were responsible comrades of the science and technology committees, the scientific and technological service companies, and the scientific and technological development and exchange centers of 16 cities, including Guangzhou, Nanning, Changsha, Zhengzhou, and Wuhan, from 5 provinces in Central-South China. The conference decided to strengthen scientific and technological services and cooperation among the cities. [Summary] [Wuhan Hubei Provincial Service in Mandarin 1100 GMT 17 Jun 84 HK]

TIANJIN TECHNOLOGY CENTER EXCHANGES--Tianjin, 18 June (XINHUA)--The Tianjin Center for Foreign Scientific and Technical Exchange organized 30 exchanges with 90 experts from 12 countries and regions in the first 5 months of this year. Items discussed included joint development of the local geothermal energy resources and co-production of equipment for seawater desalinization. An increasing number of foreign concerns are interested in trade with this important North Chinese industrial city and need the technical, commercial and legal consultancy that the center can provide, said the center's Secretary General Lu Zhiyuan. Established in 1979, the center had brought 1,600 experts to the city from more than 20 countries and regions and handled 850 exchanges by the end of last year. It has organized lectures on 50 subjects and sent 133 people abroad for surveys, study and conferences. This has boosted the local economy and improved links with other countries. [Text] [OW181001 Beijing XINHUA in English 0650 GMT 18 Jun 84]

CHEMICALS EXHIBIT IN HONG KONG--Hong Kong, 2 July (XINHUA)--An exhibition on Chinese chemicals and pharmaceuticals will run from Wednesday until 18 July in the Hong Kong exhibition center. It is being jointly sponsored for the first time in Hong Kong by the China National Chemicals Import and Export Corporation (CNCIEC) and the China National Medicines and Health Products Import and Export Corporation (CNMHPIEC). About 1,000 items will be displayed, including petroleum and its by-products, raw chemicals, chemical reagent, dyes, pigments, paint, printing ink, rubber and talex products, pharmaceutical raw materials, medical equipment, medicines and dressings. Zhu Dazhi, head of the exhibition group and deputy general manager of the CNCIEC, said China had achieved rapid progress in its oil, chemical and pharmaceutical industries since 1949. Import and export volume of chemicals and medicine in 1983 totaled more than U.S.$8 billion (17 billion yuan), about 49 times as much as the 1950 figure. China now trades more than 1,000 varieties of chemicals and medicines with 130 countries and regions, Zhu said. [Text] [OW021558 Beijing XINHUA in English 1443 GMT 2 Jul 84]

HUBEI SCIENTIFIC, TECHNOLOGICAL BUREAU--The provincial CPC Committee and Government have decided to establish a Scientific and Technological Information Bureau as a functional organ for controlling the province's scientific and technological information. The provincial government has also made a decision to build a scientific and technolgoical information center, which will be designed this year and built next year. Meanwhile, the provincial scientific and technological commission is actively making preparations to establish a microcomputer information network to gradually update the work of scientific and technological information. The provincial Scientific and Technological Commission has also decided to offer a scientific and technological information course at Hubei College for training scientific and technological cadres, which will soon be established as a base for training personnel engaged in scientific and technological information in our province. [Text] [HK211356 Wuhan Hubei Provincial Service in Mandarin 1100 GMT 20 Jun 84]

NEI MONGOL RESEARCH CENTER--A new research institute--the Alxa Desert Research Center--was formally established in Alxa League in early June. The main task of this research center is to explore ways to cultivate deserts so as to attain the goal of improving and utilizing deserts. [Summary] [SK270144 Hohhot Nei Mongol Regional Service in Mandarin 1100 GMT 24 Jun 84 SK]

CSO: 4008/34

SYSTEM FOR ESTIMATING TORPEDO RELIABILITY EXPLAINED

Shanghai CHUANBO GONGCHENG [SHIP ENGINEERING] in Chinese No 2, 1 Apr 84 pp 47-53

[Article by Liu Qun [0491 5028], Chen Zhijun [7115 1807 6874], and Sun Yaode [1327 5069 1795]: "Synthetic Estimation of Torpedo System Reliability"]

[Excerpts] A torpedo is a complex system that ordinarily consists of a power sub-system, a control sub-system, a guidance sub-system, a detonation sub-system, and a torpedo hull sub-system. In addition, each sub-system is composed of various complete machines, and each complete machine may be further broken down into a sub-order of modules or principal assemblies. Thus, it is possible to draw a pyramidal structure consisting of "the complete torpedo system--sub-systems--complete machines--principal assemblies." Each part at each level has its own functions, and a logic diagram with "complete functioning of the whole torpedo" at its peak may be drawn on the basis of the logical relationship among the functions of individual parts at all levels.

In testing and using torpedoes, certain data are derived for all parts (components) at all levels on the logic diagram. We have proceeded from these data and the logic diagram to evaluate statistically the reliability of the entire system.

1. Collecting Data

Reliability means the probability that the product will complete stipulated functions under stipulated conditions of use and within a stipulated time. What we want to evaluate is inherent product reliability at any given stage in the development of the product. Inherent reliability reflects the level of the products' research and production. We used the reliability parameters of the design and production levels of the product at the present stage as a matrix, and we regarded the data derived from testing of sample pieces as sub-samples taken from this matrix. Degree of reliability was evaluated on the basis of these sub-samples, and sub-samples had to be representative. In collecting data, it is imperative to determine first of all the "functioning" of the product (systems, sub-systems, the whole machine, and principal assemblies are all products), and it is imperative to define what is a "product trouble." Inasmuch as the process of testing and using complex

systems is fairly complicated, since numerous factors have a bearing, and since the bearing is wide, an engineering analysis must be made of all data derived.

Without doubt, the emphasis when collecting data should be on analysis of product troubles, and every effort should be made to analyze fairly thoroughly and clearly the circumstances surrounding troubles and the reasons for their occurrence. Study of reliability means studying troubles of a random nature. We have divided product troubles into three categories as follows:

(1) Flaws that do not have much effect on system functioning

(2) Troubles that cause decline in performance, but despite a decline in product performance indicator parameters, function has not been completely lost. This state of affairs is termed troubles that cause a decline in performance. Experiments on sample pieces of this sort require maintenance of a fairly objective attitude.

(3) Fatal troubles that lead to loss of function, which may not be omitted when processing data.

Experiments may fail for various reasons, with desired results not being obtained. Then the following analysis of troubles that have occurred should be done:

(1) Fatal troubles of unknown origin should be treated as trouble data in the evaluation of reliability.

(2) Troubles, the cause of which have been found but for which no avoidance actions exist as yet. These should be treated as trouble data for evaluating reliability.

(3) Troubles for which the reasons have been found, and which it is possible to eliminate after taking effective technical and managerial actions. These should not be directly figured into trouble data, and experiments at the present level should not be made a part of statistics. Instead, analysis should be done at the next lower level, and at the lower level, components should be classed as "normal," "trouble," or "not a part of statistics" depending on circumstances.

(4) All troubles resulting from violation of design requirements and technological requirements, or from contravention of operating regulations are termed "avoidable man-made troubles." Troubles with test equipment or testing techniques may also cause experiments to fail. Such troubles are not troubles inherent in the products themselves, and should, depending on circumstances, either not be made a part of statistics, or else analyzed as assemblies at a lower level and made a part of statistics.

2. Interval Appraisal of Reliability

Reliability data is best obtained from special reliability experiments. Under special circumstances, they may also be obtained from debugging or

from use. The data that can be collected usually fall into three categories as follows:

(1) Failure type reliability data: the number of experiments is n; the number of successes is S, and the number of failures is F.

(2) Life expectancy type data: Number of specimens tested is n; life expectancy is t_j (j = 1,2,..., n), or experimentation time is t_i (i = 1, 2, ..., n); number of failures is Z; and job time is t_o.

(3) Performance parameters data: Number of specimens tested is n; performance parameters are x_i(i = 1, 2, ..., n); permissible upper and lower limits are x" and x'.

Data [1] and [2] discuss in detail handling methods for these data, i.e. they use evaluation functions to describe the interval calculations of reliability. R may be used to express "recognition" of the degree of reliability based on experimental data. It is a random variable, and the probability distribution function that R satisfies is a reliability evaluation function.

$$F_R(R_L) = P\left\{R \leqslant R_L\right\} = 1 - \gamma \tag{1}$$

It is the function of the lower limit of reliability, R_L. As for success and failure type data and index distribution life expectancy data, analytic indications of evaluation functions already exist. Ready made tables are also available for use on normal distribution performance data.

3. Weibull Overall Reliability Evaluation Functions

Following examination of statistics, if product life expectancy data do not come from index distribution totals for which one is responsible, but instead come from Weibull distribution totals, then the Weibull distribution density function of the two parameters is as follows:

$$f(x, b, c) = \left(\frac{c}{b}\right)\left(\frac{x}{b}\right)^{c-1} e^{-\left(\frac{a}{b}\right)^6} \tag{2}$$

The maximum likelihood method may be used to derive the estimated value of parameters b and c's point estimated value $\hat{b}$ and $\hat{c}$. They fit the following formula:

$$\begin{cases} \dfrac{n}{\hat{c}} - n\dfrac{\sum_{i=1}^{n} x_i^{\hat{c}} \ln x_i}{\sum_{i=1}^{n} x_i^{\hat{c}}} + \sum_{i=1}^{n} \ln x_i = 0 & (3) \\ \hat{b} = \left(\sum_{i=1}^{n} \dfrac{x_i^{\hat{c}}}{n}\right)^{1/\hat{c}} & (4) \end{cases}$$

Thoman, Bain and Antle [3] provided a method for the interval calculation of the two parameters. They proved that $\frac{\hat{c}}{c}$ and $\hat{c}_{11}$ have identical probability distribution, and they also proved that $\hat{c}\ln\frac{\hat{b}}{b}$ and $\hat{c}_{11}\ln(\hat{b}_{11})$ have identical probability distribution. In this formulation, c_{11} and b_{11} are the most likely estimated values of c and b when standard index distribution is sampled. Moreover, the distribution functions of $\hat{c}_{11}$ and of $\hat{c}_{11}\ln(\hat{b}_{11})$ may be readily obtained by using the Monte Carlo method. All that is needed is a sampling of the standard index distribution to obtain $x_i (i = 1,2,\ldots, n)$, after which formulas (3) and (4) may be used to solve for $\hat{b}_{11}$ and $\hat{c}_{11}$, and to calculate $\hat{c}_{11}$ and $\hat{c}_{11}\ln(\hat{b}_{11})$, i.e. to obtain their first sampling value. As the number of samplings becomes sufficient, the sought after distribution functions may be obtained. Then they may be used as the distribution functions of $\hat{c}/c$ and of $\hat{c}\ \ln\frac{\hat{b}}{b}$.

Take 1_{i_1} to represent the $\frac{\hat{c}}{c}$ distribution percentage position, the distribution function of c is as follows:

$$F_c\left(\frac{\hat{c}}{l_{\nu_1}}\right) = P\left\{C \leqslant \frac{\hat{c}}{l_{\nu_1}}\right\} = 1 - \nu_1 \tag{5}$$

Take 1_{ν_1} to represent the $c\ \ln\frac{\hat{b}}{b}$ distribution percentage position, b's distribution function may be derived as follows:

$$F_b\left\{\hat{b}\exp\left(-\frac{l_{\nu_2}}{\hat{c}}\right)\right\} = P\left\{b \leqslant \hat{b}\cdot\exp\left(-\frac{l_{\nu_2}}{\hat{c}}\right)\right\} = 1 - \nu_2 \tag{6}$$

We have subordinated life expectancy to the Weibull distribution of product reliability as follows:

$$R = \exp\left[\left(-\frac{x}{b}\right)^c\right] \tag{7}$$

which are regarded as functions of random variables b and c. R is also a random variable, whose distribution function may readily be obtained through use of the Monte Carlo method. By sampling (approximate sampling in steps) the distribution function of F_c, the first sampling value of C may be derived. By sampling the distribution function of F_b, the first sampling value of b may be derived. When substituted in formula (7), the first time sampling value of R may be derived. Repeated samplings taken many times will produce an R frequency diagram. When the number of tests are sufficient, the results may be substituted for the R probability distribution function as follows:

$$F_R(R_L) = P\{R \leqslant R_L\} = \alpha \tag{8}$$

This is the sought after reliability evaluation function of the Weibull distribution total. The first and second moments of R may be derived by using numerical value integrals as follows:

$$\mu = 1 - \int_0^t F_R(R_L)dR_L \tag{9}$$

$$\nu = 1 - 2\int_0^t R_L F_R(R_L)dR_L \tag{10}$$

4. Models for "Performance Decline Troubles"

Product performance parameters may frequently be regarded as random variables subordinate to gaussian distribution. In dealing with these data, the sampling values of test samples are judged reliable within designated limits, otherwise there is trouble with the product. There are only two states here as explained in Figure 2 (1). However, for numerous products, performance parameters show minute changes near the edges without impairment to their main functioning. This amounts only to a decline in performance. Thus, it is imperative to note the existence of a situation of "performance decline troubles." Though performance of products in this situation has declined, the products can continue to function.

In order to deal with this kind of problem, we have introduced the "value function" concept [4]. In figure 2, $u_0(x)$, $u_1(x)$, and $u_2(x)$ are a few representative value functions, and $f_0(x)$, $f_1(x)$, and $f_2(x)$ are functions of performance indicator distribution density. Meanwhile, x" and x' provide the upper and lower limits, while x_2 and x_1 are indicators values with a value of 0. Thus product reliability is as follows:

$$\begin{aligned} R_0 &= \int_{x'}^{x''} u_0(x) f_0(x)dx \\ &\doteq \int_{x'}^{x''} f_0(x)dx \\ &= \int_{x'}^{x''} \frac{1}{\sqrt{2\pi}} e^{\frac{1}{2\sigma^2}(x-\mu)^2}dx \end{aligned} \tag{11}$$

$$R_1 = \int_{x_1}^{x_2} u_1(x) f_1(x)dx \tag{12}$$

$$R_2 = \int_{x_1}^{x_2} u_2(x) f_2(x)dx \tag{13}$$

The values of x_1 and x_2 as well as the specific form of value functions are to be determined by engineering realities.

How can one use test data to estimate the reliability expressed in the foregoing formulas? Strictly speaking, it is necessary to find their reliability evaluation functions, yet this reliability evaluation function is not easily expressed. In engineering projects where not much data are available, a conservative estimate may be made, converting them to failure type data. If test data appear between x_1 x'' and x", the number of successes, S, and the number of failures, F, are fulfilled

$$0 < S < 1, \qquad F = 1 - S$$

Neither S nor F is either 1 or 0.

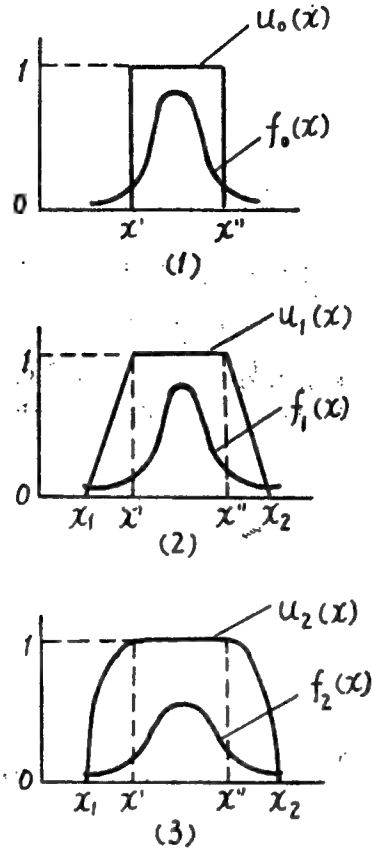

Figure 2

5. Steps in Evaluating Systems Reliability

The following several steps may be carried out for the synthetic evaluation of complete torpedo systems:

(1) Construction of a logic diagram for the functioning of complete torpedo systems as shown in Figure 1. The figure shows logic relationships among stages, namely parallel and series relationships. In construction of a logic diagram, it is necessary to note that the various individual components in the same switching gate must be mutually independent.

In Figure 1, the data for the peak $A = B_1 \cap B_2$, B_1 are test data for "space tracking." They are a rather synthetic kind of testing; however, they do not include testing of detonator explosions. Since the B_1 data is able to reflect the product test situation more realistically than data at the next lower level, we will not continue the breakdown of data for each system. Clearly the establishment of switching gates on the logic diagram is not entirely determined by engineering systems and the relationship of main components.

In Figure 1, the guidance sub-system's "ability to find targets" and "ability to track targets" are by no means mutually independent matters, but in

the synthetic method, they are regarded as independent hypotheses. We can use conditional probabilities to deal with this kind of problem as follows:

$$\begin{aligned} & P \quad \text{(guidance function okay)} \\ = \; & P \quad \{\text{ability to find and track the target}\} \\ = \; & P \quad \{\text{ability to find}\} \; P \; \{\text{ability to track/ability to find}\} \end{aligned}$$

Test data on the guidance sub-system must be handled in accordance with these requirements. The detonator sub-system's "error-free action" and the "ability to explode" are also not mutually independent matters, and should be similarly treated.

(2) When data are collected, the kinds of data and results are written into the proper position on the logic diagram.

(3) Stage synthesis means to synthesize next stage test data attributable to the same switching gate into corresponding previous stage conversion data. In order to bring about such an approximate synthesis, system reliability first and second moment has to be obtained from the system switching gate; additionally the reliability first and second moment has to be obtained from the system reliability approximate evaluation function, and a relationship established between the two in order to educe an approximate synthesis formula. The "AND gate" (reliability series) is as follows:

$$\left.\begin{aligned} n &= \frac{1-\frac{B}{A}}{\frac{B}{A}-A}-1 \\ F &= (n+1)(1-A)-1 \\ A &= \prod_{j=1}^{i}\frac{S_j}{n_j+1}\prod_{K=1}^{m}\left(\frac{\eta_K}{\eta_K+1}\right)^{z_{K+1}}\prod_{t=1}^{q}\mu_t \\ B &= \prod_{j=1}^{i}\frac{S_j(S_j+1)}{(n_j+1)(n_j+2)}\prod_{K=1}^{m}\left(\frac{\eta_K}{\eta_K+2}\right)^{z_{K+1}}\prod_{t=1}^{q}\nu_t \end{aligned}\right\} \qquad (15)$$

$$\left.\begin{aligned} \frac{\ln\left(\frac{\eta+1}{\eta}\right)}{\ln\left(\frac{\eta+2}{\eta+1}\right)} &= \frac{\ln A}{\ln B} \\ Z &= -\frac{\ln A}{\ln\left(\frac{\eta+1}{\eta}\right)}-1 \end{aligned}\right\} \qquad (16)$$

The "OR gate" (reliability parallel) is as follows:

$$
\left.
\begin{aligned}
n &= \frac{C-D}{D-C^2} - 1 \\
F &= (n+1)C - 1 \\
C &= \prod_{j=1}^{i} \frac{F_j+1}{n_j+1} \prod_{K=1}^{m} \left[1 - \left(\frac{\eta_K}{\eta_K+1}\right)^{S_K+1}\right] \prod_{i=1}^{q} (1-\mu_i) \\
D &= \prod_{j=1}^{i} \frac{(F_j+1)(F_j+2)}{(n_j+1)(n_j+2)} \prod_{K=1}^{m} \left[1 - 2\left(\frac{\eta_K}{\eta_K+1}\right)^{S_K+1} + \left(\frac{\eta_K}{\eta_K+2}\right)^{S_K+1}\right] \\
&\quad \prod_{i=1}^{q} (1 - 2\mu_i + \nu_i)
\end{aligned}
\right\} \qquad (17)
$$

$$
\left.
\begin{aligned}
Z &= -\frac{\ln(1-C)}{\ln\left(\frac{\eta+1}{\eta}\right)} - 1 \\
\frac{\ln\frac{\eta+1}{\eta}}{\ln\frac{\eta+2}{\eta+1}} &= \frac{-\ln(1-C)}{\ln(1-C) - \ln(1-2C+D)}
\end{aligned}
\right\} \qquad (18)
$$

Either formula (15) or formula (17) may be used to calculate that switching gate's converted success or failure type data n and F from the same switching gate's test data n_j, S_j η_K, Z_K, μ_i, and ν_i. Either formula (16) or formula (18) may be used to figure converted life expectancy type data η and Z.

(4) If we express as n'', S'', η'', and Z'' the converted switching gate data calculated in the previous step, and express as n', S', η', and Z', the direct test data from that switching gate in the previous previous stage, the weighted addition of the two will yield synthetic data for that switching gate during the previous stage as follows:

$$
\left.
\begin{aligned}
n &= n' + n'' \frac{1}{K} \frac{t_1}{t_2} \\
F &= F' + F'' \\
\eta &= \eta' + \eta'' \frac{1}{K} \frac{t_1}{t_2} \\
Z &= Z' + Z''
\end{aligned}
\right\} \qquad (19)
$$

In this formula, K represents environmental factors, which may be synthetically calculated from actual environmental test data and from laboratory test data. This will reflect differences in the environment during testing and at the time of actual use. The symbols t_1 and t_2 individually express job times for next stage components and previous stage systems.

(5) The carrying out of two step handling of all switching gates for systems function logic diagrams up to the very peak yields synthetic data for all torpedo systems n_s, F_S, S_s or η_s and Z_s.

(6) To figure the lower limits of confidence in the reliability of the entire torpedo system, if the complete torpedo system's synthetic results are success or failure type data n_s, F_S, or S_s, functions may be evaluated in terms of success or failure type reliability as follows:

$$\begin{aligned} F(R_L) &= \sum_{i=S}^{n} C_n^i R_L^i (1-R_L)^{n-i} \\ &= \frac{\Gamma(n+1)}{\Gamma(S)\cdot\Gamma(F+1)} \int_0^{R_L} R^{S-1}(1-R)^F dR \\ &= 1-v \end{aligned} \tag{20}$$

Calculation of the lower limits of reliability, R_L, will simultaneously yield degree of confidence, v. Actually, prior calculations are placed on a chart for review. When $F_S \leqslant 10$, the data in [5] may be looked at.

If the synthetic results for all torpedo systems are index distribution life expectancy type data η_s and Z_S, the lower limits of reliability may be figured in terms of distribution reliability evaluation functions, or an approximate formula may be used as follows:

$$\left.\begin{aligned} T_L &= \frac{2\tau}{x^2_{2(Z+1),v}} \\ R &= \exp\left\{ -\frac{x^2_{2(Z+1),v}}{2\eta} \right\} \\ \eta &= \frac{\tau}{t_0} = \frac{\sum_{i=1}^{n} t_i}{t_0} \end{aligned}\right\} \tag{21}$$

Calculation of the lower limits of average life expectancy, T_L and the lower limits of reliability, R_L will yield the extent of confidence, v at the same time. In this formulation, x^2_2 (Z + 1), v is the x_2 distribution percentage position when the degree of freedom is 2(Z + 1).

6. Several Understandings

The problem of evaluating systems reliability through testing of small samples is a special one. This synthetic evaluation method may fairly equitably deal with some of the problems occasioned by "small samples."

(1) Since the amount of test data from small samples is limited, level estimates must be made for both systems and components in order to derive confidence intervals for the degree of reliability and the extent of confidence. Data that may be handled includes readily available success and failure data, index distribution, Weibull distribution life expectancy type data, gaussian distribution performance parameter data, and "performance decline trouble" type data.

(2) Test data for the whole system is less than data for sub-systems and components. In order to improve accuracy of evaluations, it is necessary to make full use of data at all levels below the peak of the logic diagram in order to expand the amount of information available.

(3) Reliability of components and of systems is expressed in terms of confidence intervals and degrees of confidence. Reliability calculations from bottom to top are by no means direct calculations of the lower limits of reliability, but are rather functional level conversions of test data.

(4) On the functional logic diagram, the closer one gets to the peak, the more important the data, and the greater the affect on synthetic estimation results. This is commensurate with understandings gained through direct observation. Thus, if the various levels of test data near the peak are complete, it is not necessary that the logic diagram be drawn all the way down to the most basic components.

References

[1] He Guowei [0149 0948 0251], "Reliability Synthesis of Weapons Systems," a selected treatise from the first annual meeting of the Chinese Electronics Society, p 100, 1981.

[2] Hu Changshou [7579 2490 1108], Zhou Zhengfa [0719 2973 0127], and Liu Zhenni [0719 2973 0127], "Basic Methods For Evaluation Reliability of Complete Machines," a selected treatise from the first annual meeting of the Chinese Electronics Society, p 111, 1981.

[3] Darrel R. Thoman, Lee J. Bain, and Charles E. Antle, "Inferences on the Parameters of the Weibull Distribution," Technometrics Vol 11, No 3, August 1969.

[4] A. D. (Yepifanofu), translated by Zhang Yanlin [1728 3601 2651], "Reliability of Control Systems," National Defense Industries Press, 1979.

[5] "Confidence Limits for Attributes Data," AD-696967, 1966.

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PHOTOVOLTAIC DETECTOR WITH THERMOELECTRIC COOLER DEVELOPED

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[Article by Feng Zhichao [7458 1807 6389], Hu Yu [5170 3254] and Hua Weishi [5478 3634 1395] of the Institute of Applied Physics, Chengdu Telecommunications Engineering College: "Development of the Modules of the Photovoltaic HgCdTe Detector with Thermoelectric Cooler"]

[Text] Abstract

In this paper we report the development of photovoltaic HgCdTe detector modules with the six-stage semiconductor cooler. The blackbody detectivity D*(500,1000,1) of the modules is 3×10^7 cm $Hz^{\frac{1}{2}}W^{-1}$. The modules were successfully used in the 10.6 μm CO_2 laser communication system.

I. Introduction

The 10.6 μm CO_2 laser has been widely used in laser communications, laser ranging and laser radar. All these systems require wide-band high-sensitivity detectors. The HgCdTe detector, working at a temperature of 77K, has a very high detectivity and a very wide band at 10.6 μm. However, the requirement of liquid nitrogen cooling is inconvenient and limits the utility of this detector. It is therefore of considerable interest to raise the operating temperature of the HgCdTe detector.[1,2] In 1976, Tang Dingyuan [3282 1353 0337] analyzed theoretically the detectivity of light-guided HgCdTe detector work at close to toom temperature and discussed the possibility of raising the operating temperature of this detector. In 1981, in collaboration with the Kunming Institute of Physics, we studied the photovoltaic HgCdTe device cooled by dry ice to -80°C and obtained the experimental result[4] of D* = 10^7 cm $Hz^{\frac{1}{2}}W^{-1}$. Recently, using a six-stage semiconductor cooler, we developed a sealed photovoltaic HgCdTe detector module. The detectivity D* and the cutoff wavelength λ_o of the module are both better than the dry-ice cooled unit. We have successfully used the modules in a 10.6 μm CO_2 laser atmospheric communications system.

II. Structure and Thermal Insulation of the Module

Figures 1 and 2 are, respectively, a photograph of the device and the schematic diagram showing the construction of the module.

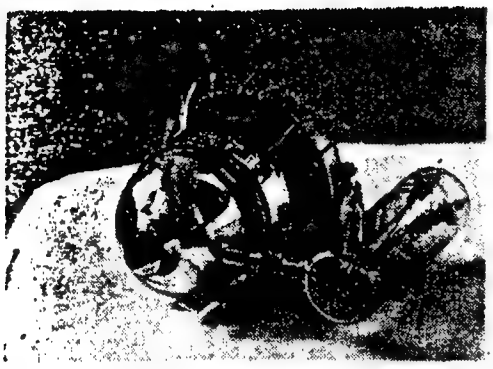

Figure 1. Detector Module

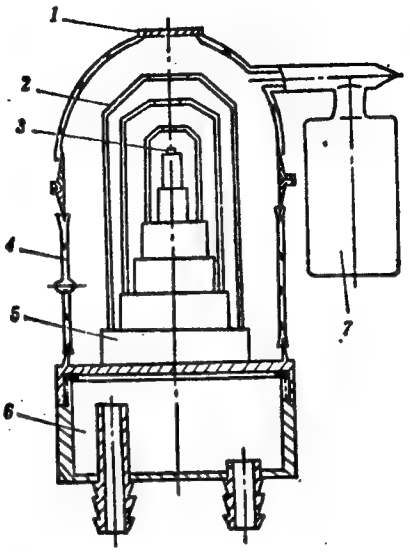

Figure 2. Schematic Diagram of Module Construction

KEY [to Figure 2]:

1. Infrared window
2. Cold shield
3. HgCdTe element
4. Glass dewar
5. Semiconductor cooler
6. Coolant water tank
7. Titanium sublimation pump

The module is housed in a glass dewar and has a six-stage semiconductor cooler. According to the literature,[5] $10^{-5}\sim10^{-6}$ Torr of vacuum is generally required if the cold tip of the six-stage cooler is to be at a temperature lower than -80°C. However, the HgCdTe element cannot withstand baking at above 100°C, and the semiconductor cooler, having a relatively large volume (42x42x52 mm^3) and made of bismuth telluride and beryllium oxide ceramics, contains 90°C solder and cannot withstand high-temperature outgassing either. As a result, the sealed module usually has only 10^{-1} Torr of vacuum or lower and cannot meet the cooling requirements. We overcame this difficulty by using a titanium sublimation pump to absorb the gas in a sealed thermoelectric HgCdTe cooling module. When operating, a current is passed through the titanium pump for 2 minutes and the vacuum in the unit can reach 10^{-5} Torr or better and the cooling temperature can reach -90°C to -96°C. After each sublimation pumping, our module can be operated for 10 days and as the number

of sublimations increases the operating time after each sublimation also lengthens. If the module is storaged for several months without using, a high vacuum can still be obtained by turning on the titanium pump. Based on the life of our titanium pump, our unit may be operated continuously for more than 10,000 hours at the vacuum required by the cooler and can be operated even longer after replacing the pump.

To achieve a lower cooling temperature, we also added a cold shield on the six-stage semiconductor cooler to reduce the external thermal radiation and the conduction of heat due to the residual gas molecules. Experiments show that the temperature of the cold tip of a six-stage cooler equipment with a three-stage radiation shield is 10-13°C lower than a cooler without the shield, as shown in Figure 3. In addition, we also coated the inner surface of the glass dewar with aluminum to reduce the radiation heating. The lead connecting the dewar wall and the cold tip has a small diameter for less heat conduction.

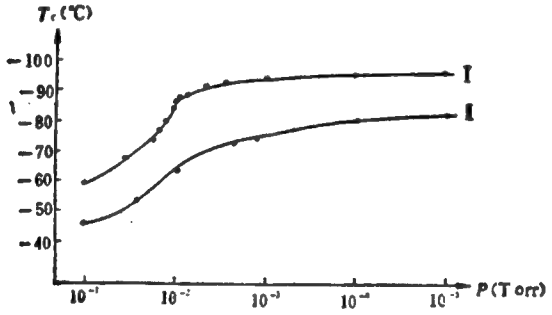

Figure 3. Temperature of the Cold Tip as a Function of Vacuum (Module No 1)

I. Three-stage thermal shield: 4.8A of current, 22°C cooling water

II. Without thermal shield: 4.8A of current, 18°C cooling water

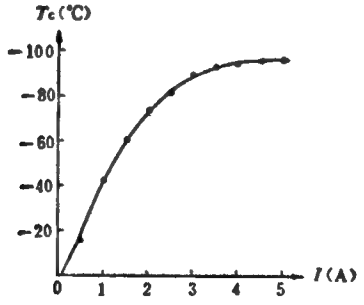

Figure 4. Temperature of Cold Tip as a Function of Current (Module No 1) at 10^{-4} Torr Vacuum and 13°C Cooling Water

Figure 4 shows the temperature T_o of the cold tip of the cooler as a function of the current I. The temperature is measured with a copper-constantan thermocouple attached on the cold tip of the cooler.

Using Module No 3 as an example, the specifications of our modules are: operating current = 4A, input power N = 30W, vacuum P = $10^{-4}\sim5\times10^{-6}$ Torr, cooling water temperature T = 30°C, cold tip temperature T_o = -92°C and cooling power Q = 15mW.

We have repeatedly tested our modules in Kunming and Chengdu and did not observe any frosting or sweating of the dewar wall or the infrared window even when the humidity was more than 90 percent. The operation was convenient and reliable.

III. Performance and Testing

The photovoltaic HgCdTe detector is chosen from low-temperature HgCdTe elements with a composition of x = 0.2. Under the background radiation, the spectral detectivity of the detector may be calculated according to the following formula[6]:

$$D_\lambda^* = \frac{\eta(r_s)\lambda\tau_n^{1/2}}{2hC_0L_n^{1/2}n_p^{1/2}\left[1+\frac{n_b}{2n_p}\right]^{1/2}}, \qquad (1)$$

where $\eta(r_s)$ is the quantum efficiency of the device, λ is the wavelength of the incident light, τ_n is the lifetime of the p region electron, h is Planck's constant, c_o is the speed of light in vacuum, L_n is the diffusion length of the minority carrier (electrons) in the p region, n_p is the minority carrier (electron) concentration in the p region under thermal equilibrium and n_b is the steady-state, nonequilibrium electron-hole pair concentration maintained by the background radiation.

Based on the current parameters, the detectivity $D^*_{10.6\mu m}$ computed from Equation (1) for a crystal composition of $x = 0.2$ and an operating temperature of 77K is of the order of 10^{11} cm $Hz^{\frac{1}{2}}W^{-1}$. The value[4] of $D^*_{10.6\mu m}$ may reach 10^9 cm $Hz^{\frac{1}{2}}W^{-1}$ when the p region doping concentration is $N_A = 3\times10^{17}$ cm^{-3}, the crystal composition x is 0.2, the quantum efficiency $\eta(r_s)$ is 0.2 and the operating temperature is 193K. In other words, when the operating temperature is raised from 77K to 193K, the theoretical detectivity of the HgCdTe detector will decrease by 2 orders of magnitude.

Table 1. Performance Data of the HgCdTe Detector

Module no.	Testing condition	λ_p (μm)	λ_c (μm)	$D^*(500,1000,1)$ (cmHz$^{1/2}$/W)	$D^*_{\lambda_p}$ (cmHz$^{1/2}$/W)	$D^*_{\lambda=10.6\mu m}$ (cmHz$^{1/2}$/W)	R_v (V/W)	η (%)	A (mm^2)
1	LN_2	11	12	4.7×10^9	1×10^{10}	9×10^9		58	0.1
	dry ice	8.4	9.2	1.4×10^7	3.6×10^7	1.1×10^7		1.6	0.1
	unit	8.8	9.5	3.1×10^7	9.7×10^7	1.6×10^7	0.6	1.6	0.1
2	LN_2	11.5	11.7	7×10^9	1.9×10^{10}			27	0.12
	dry ice	8.4	9.6	1.6×10^7	4.4×10^7	6.5×10^6		1.4	0.12
	unit	9.2	10	2.7×10^7	7.4×10^7	1.8×10^7	0.34	2.8	0.12
3a	LN_2	11.2	12	5.6×10^9	1.6×10^{10}			60	0.12
	dry ice	8.8	9.6	1.8×10^7	4.4×10^7	5×10^6		1.5	0.12
	unit	9.2	10.1	2.8×10^7	7.7×10^7	2.1×10^7	0.32	1.7	0.12
3b	Unit	8.4	9.2	1.8×10^7	5.9×10^7	0.6×10^6	0.07	2.6	0.76

1) Cooling temperature in unit tests is -90~-96°C;
2) Module No 3 contains two HgCdTe units;
3) When measuring the spectrum response curve at the dry ice temperature, the slit width used was twice of that in liquid nitrogen (LN_2) and unit tests.

Test results show that:

1. Since the operating temperature of the module is 10-16°C lower than the dry ice temperature, the measured $D^*_{10.6\mu m}$ and the cutoff wavelength λ_c were higher.

2. Since the operating temperature of the unit was about 100K higher than the liquid nitrogen temperature, the actual measured $D^*_{\lambda_p}$ has decreased by about 2 orders of magnitude. This result is basically consistent with the theoretical analysis. When the operating temperature of a x = 0.2 photovoltaic HgCdTe detector is raised from 77K to the dry ice temperature, then on the one hand the value of $D^*\lambda_p$ will decrease and on the other hand λ_p and λ_c will move toward the shorter wavelength (actual measured average value is 2 μm). Therefore, at a wavelength of 10.6 μm, the operating point is already near the tail of the spectrum response curve, as shown in Figure 5. We believe that if the composition of the device is changed so that the spectrum response curve at 193K peaks at 10.6 μm or so, then the value of $D^*_{106\mu m}$ can be improved and 10^8 cm $Hz^{\frac{1}{2}}W^{-1}$ may be possible.

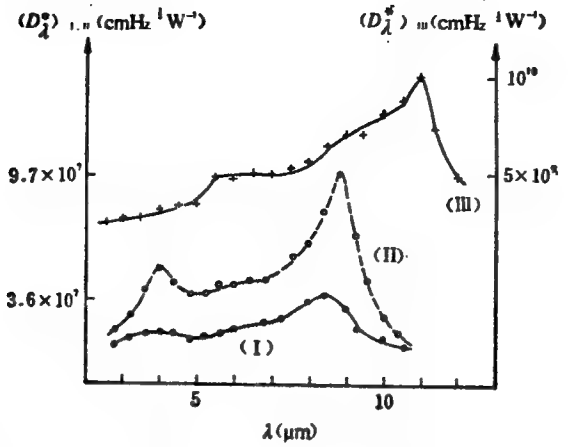

Figure 5. Spectrum Response Curve of Module No 1

I. Dry ice temperature
II. Unit-testing temperature (-96°C)
III. Liquid nitrogen temperature

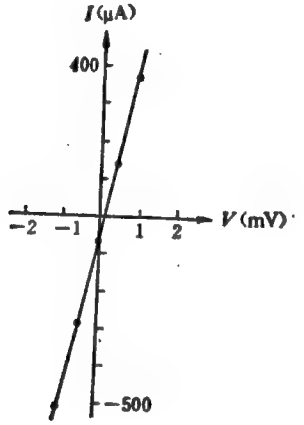

Figure 6. I-V Characteristics of the Detector
(Module No 3, Cold Tip Temperature at -92°C)

Figure 6 shows the I-V characteristics of the No 3 detector. The curve shows that as the operating temperature is raised, the reverse-situation current of the device increases rapidly, which degrades the p-n junction and greatly reduces the zero-bias resistance and the detectivity of the device.

We conducted laboratory tests of Module No 3 on a 10.6 μm CO_2 laser system and the results are shown in Table 2.

Table 2. Test Results on a 10.6 μm CO_2 Laser System

Light-sensitive area S_d(mm^2)	Gaussian-beam diameter r(mm)	Effective power on light-sensitive surface P_i(μW)	Effective output voltage of preamp U_S(mV)	Effective signal voltage E_s (μV)
0.12	30.5	40.6	14.3	9.5

Based on the data above, the voltage response of the device at 10.6 μm is R_v = 0.23 V/W. When the noise level at the input of the amplifier is E_n = 1.1 nV/$\sqrt{Hz}$ and the amplifier band width is Δf = 16kHz, we obtained, for the Module No 3, $D^*_{10.6\mu m} = 7\times10^6$ cm$Hz^{1/2}W^{-1}$ and the equivalent noise power, NEP = 4.8×10^{-9}W/$\sqrt{Hz}$. For Module No 1, we obtained $D^*_{10.6\mu m} = 1.7\times10^7$ cm $Hz^{1/2}W^{-1}$ and NEP = 1.8×10^{-9} W/$\sqrt{Hz}$.

It should be pointed out that in our CO_2 laser system, the noise of the amplifier is far greater than the noise of the HgCdTe unit and there is the potential of lowering the value of the NEP by another order of magnitude by reducing the amplifier noise.

IV. Application in 10.6 μm CO_2 laser communications systems

Using Module No 3, we conducted communications tests on a directly detected 10.6μm CO_2 laser system. The system uses a cassegrain receiving antenna and a germanium lens. The detector module is placed on the adjustable mount at the tail of the antenna. The optical path is shown in Figure 7.

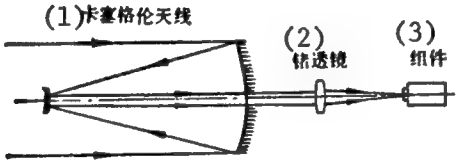

Figure 7. Receiving Light Path Diagram

KEY:

(1) Cassegrain antenna
(2) Germanium lens
(3) Module

Experimental results: At a communication distance of L = 5km and a visibility of 0.5 1 km on a foggy day, the terminal obtained a signal-to-noise ratio of 52 dB. The audio signal coming through the three-way carrier unit, was clear and had low distortion. Since the adjustable mount did not quite fit, we failed to obtain the maximum light signal. The terminal S/N ratio can be further improved by modifying the adjustable mount.

V. Conclusions

1. When thermoelectrically cooled photovoltaic HgCdTe detectors are used in the 10.6 μm wavelength range, they have a wide-frequency band width, a high sensitivity (relative to (thermoelectric?) detectors) and a low resistance. They are clearly superior to TGS and $LiTaO_3$ detectors[3] in terms of immunity to atmospheric turbulance. They can therefore be used on 10.6 μm wide-band high-capacity CO_2 laser systems. A comparison of the three types of detectors is shown in Table 3.

Table 3. Performance of Three Different Detectors as a Function of Frequency

Performance \ Device		TGS (with substrate)	$LiTaO_3$ (with substrate)	Thermoelectrically cooled photovoltaic HgCdTe device
$D^*_{10.6\mu m}$ (cm·Hz$^{1/2}$/W)	10Hz	10^8	$<10^8$	10^7
	10kHz	10^5	$<10^5$	10^7
	1MHz	10^3	$<10^3$	10^7
R_v (V/W)	10Hz	10^3	8×10^2	0.6
	10kHz	1	0.8	0.6
	1MHz	0.01	0.008	0.6
NEP (W/$\sqrt{Hz}$)	10Hz			1.8×10^{-9}
	10kHz	10^{-8}	$<10^{-8}$	1.8×10^{-9}
	1MHz	10^{-6}	$<10^{-6}$	1.8×10^{-9}

2. By using a titanium sublimation pump and by adding radiation shields on the cooler, we have solved the vacuum and thermal insulation problems of the module. The construction is very simple and reliable.

3. When the detector is used on a 10.6 μm CO_2 laser system, the signal-to-noise ratio can be improved by lowering the amplifier noise. We believe this should be possible.

4. Our present photovoltaic HgCdTe detector modules are developed for operation at the liquid nitrogen temperature and their performance is not good at the dry ice temperature. It is important to develop HgCdTe devices that operate near the room temperature. It will greatly broaden the application propects of HgCdTe detectors.

FOOTNOTES

1. Koehler, T., AD-A032851, 1976.

2. Galus, W., Persak, T., and Piotrowski, J., INFRARED PHYSICS, 19 (1979), 649.

3. Tang Dingyuan [3282 1353 0337], CHINESE JOURNAL OF INFRARED PHYSICS AND TECHNOLOGY, 4-5 (1976).

4. Ye Yutang [0673 3768 1016], CHINESE JOURNAL OF INFRARED RESEARCH, 1 (1982).

5. Wurtz, H. P., PROCEEDINGS OF THE SPIE, 246 (1980), 15-21

6. Willardson, R. K., and Bear, A. C., "Infrared Detectors," Defense Industry Publication Co., 1973 [In Chinese].

7. Qiu Mingxin [5941 2494 0207] and Hu Yu [5170 3254], JOURNAL OF THE CHENGDU COMMUNICATIONS ENGINEERING COLLEGE, 2-3 (1979).

9698
CSO: 4008/225

REPAIRING AND OPERATING A HIGH-PRESSURE CANNED PUMP

Chengdu HE DONGLI GONGCHENG [NUCLEAR POWER ENGINEERING] in Chinese Vol 5, No 2, Apr 84 pp 37-40

[Article by Guo Zhongchuan [6753 1813 1557]]

[Text] Abstract: The paper discusses the successful repair of a pump in 1980 and summarizes more than 10 years of experience in testing, repairing, and operating a high-pressure vertical canned pump.

1. Introduction

Canned pumps are critical components in experiments in high-pressure thermal engineering. We encountered many problems in using our two high-pressure vertical canned pumps, in addition to difficulties caused by the continual interruptions of the thermoengineering experiments necessitated by faulty pumps. Since the pumps were operated continuously for only 10 or 20 hours in the experiments, the pumps had to be switched on and off quite frequently, and as a result they invariably failed during test runs.

We struggled with this situation for 10 years, during which time we repaired the pumps as required during the experiments; however, we did gain experience in operating the system and eventually succeeded in fixing the pumps on two occasions.

2. Brief Description of the 4PL8 Canned Pump and Its Shortcomings

The 4PL8 canned pump which we employed has a discharge of 80 m^3/h and a lift of 80 m, and the shaft of the canned electrical motor operates at a power of 35 kW. The working medium (deionized water) is at high pressure (140 kg/cm^2) and temperature (300°C). The upper and central portions of the pump motor were thermally insulated by a maze-like central structure surrounded by air pockets (the insulation also served to control the escape of high-pressure water from the top of the closed loop). A small portion of the working medium injected into the pump is forced by the upper auxiliary propeller through gaps near the shaft bearing and between the rotor and stator, through the cooling coils wound around the stator, and back again to the auxiliary propeller, so that the working medium circulates along a closed loop. The heat from the motor and shaft bearing and the heat transferred to the circulating medium can also be removed by a secondary cooling system using running tap water.

Figure 1 shows the principal components of the pump, which are as follows:

The canned three-phase asynchronous electric motor rotating at 2900 rpm is insulated by class H insulation and housed in a 0.4-mm-thick inconel alloy case. The sliding axial and thrust bearings are made from FK-1F graphite plastic. The graphite cylinders in the top and bottom guide bearings contain axial grooves and the upper thrust bearing tiles are radially grooved in order to facilitate the flow of cooling and lubricating liquid. A novel structure with six central graphite support tiles is used in the lower portion of the guide bearings in thebottom thrust bearing assembly. These thrust tiles automatically handle the vibrations and oscillations of the rotor and the thrust washers and provide a stable lubricating liquid film between the rotor and the thrust washers. The rotor shaft and the thrust washers are soldered where they come into contact with the bearings using B-3K alloy ($Rc \geq 41$) of $\nabla 10$ smoothness class.

Numerous manufacturing defects were discovered in the two pumps. For example, the coils were not protected from contact with water, so that electrical breakdowns occurred; there was excessive shaft wear; and the components were not dynamically balanced (i.e., not in dynamic equilibrium). The pumps also failed the on-site tests--the main difficulties were due to the inlet ring and the bottom thrust bearings and washers. Although we enlarged the inlet ring, increased the diameter of the balancing hole in the main propeller, reduced the siae of the main propeller, aligned the shaft and corrected the dynamic balance of the rotor, adjusted and ground down the lower thrust bearings, tested the pump under no-load conditions, and sent it back to the factory for repairs, none of these measures was successful even after dozens of hours of repairs, hundreds of hours of testing, and more than 1,000 hours of operation. Even after checking the shaft and precisely adjusting the dynamic balance of the rotor, adjusting and grinding down the lower thrust bearings, buffing the thrust washers, and selecting suitable guide bearings, we could not get the pump to turn on normally for more than 20 or 30 times and failure would occur after 200 or 300 hours of operation.

This state of affairs continued until 1975, when we replaced the bottom thrust bearings by "eccentric support bearings"; this enabled us to switch the pump on more than 100 times and operate it for more than 1,000 hours without a malfunction.

3. Repairs Made in 1980

1. Brief Description. After the successful repairs in 1975 the pump operated without failure until 1980, when experiments at reduced pressure revealed that water was leaking into the stator cavity (from the inlet used to measure the pressure and temperature). There was thus no choice but to take the pump apart and repair it. During the inspection we also found that friction had eroded the three adjacent bottom thrust tiles by several tens of micrometers. Although the tiles could continue to be used for a while, a long time would have been required to replace the stator

housing. Since we were eager not to interrupt the thermoengineering experiments, we used the motor of the other pump, which had not been modified. As a result, its tiles already showed considerable wear and had to be replaced, and the guide bearings were also worn; however, the thrust washers, which contained scratches like the grooves in a record, were still usable.

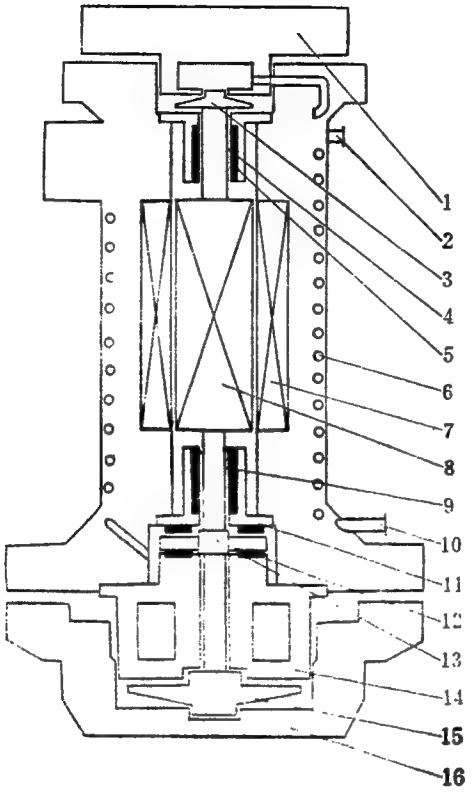

Fig. 1. 1) top cover; 2) inlet for secondary water cooling system; 3) axial proprller; 4) upper shaft; 5) upper guide bearings; 6) primary water cooling system coils; 7) stator; 8) rotor; 9) lower shaft; 10) outlet of secondary water cooling system; 11) lower guide bearings; 12) thrust washers; 13) lower thrust bearing assembly; 14) thermal insulation 15) main propeller; 16) pump housing.

2. Summary of Repairs

1) The guide bearings were replaced by new tiles with suitable clearances.

2) The lower thrust bearing assembly was polished and adjusted.

Each lower thrust tile was first placed on a flat bench, covered with paraffin, and polished to 6-7 smoothness class so as to increase the contact surface area to more than 70 percent. The central support tiles were then replaced by eccentric tiles (cf. Fig. 2), which were partly abraded on the side nearest the water outlet (the rotor rotates counterclockwise in Fig. 2). In other words, we removed some of the pressure-resisting surface

from the shaft bearings so that their shape was eccentric when the pump was in operation. It was essential to ensure that all of the tile surfaces were at the same height in the bottom thrust bearing assembly and that they were in contact with the thrust washers. Finally, the tiles were abraded simultaneously on a level bench in order to align their surfaces as evenly as possible.

3) After assembly the system was tested successfully and found to be ready for use.

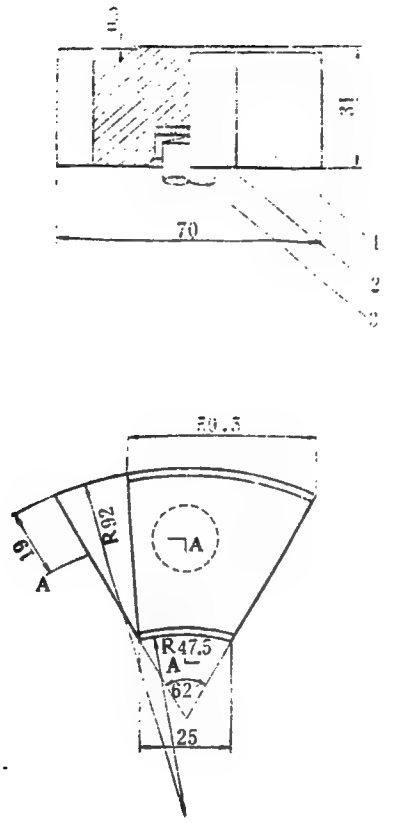

Fig. 2. Tiles in the bottom thrust bearings. 1) graphite tile; 2) support shim; 3) support screw

4. Summary of Our Experience with the Pump

The improved pump with eccentric thrust bearings operates much more stably than the unmodified pump using a central support structure in its lower thrust bearing assembly. Moreover, since the experiments required turning the pump on and off once or twice a day, the pump components were subjected quite often to brief frictional forces which greatly increased the wear on the shaft bearings. Since we had to polish the surfaces of the bottom thrust tiles by hand (which gives results inferior to those obtained by the pressure-rolling technique used outside China), quality was difficult to ensure under our conditions. As it turned out, the pumps with central support lower thrust bearings did not perform acceptably under our operating conditions.

The rotor and the lower thrust bearing tiles in the canned pumps are both immersed in the high-pressure water injected into the system. The rotor spins rapidly on top of the bottom thrust bearing tiles, and normal operation requires that a water film be present between the rotor thrust washers and the bottom tiles. The pressure on the water film must be equal to the pressure in the system. Under ideal operating conditions, there are no breaks in the film and the downward thrust on the film is equal to the weight of the rotor minus bouyant forces and the upward thrust produced (intentionally) by the presence of the balancing hole in the main propeller and by the inlet ring. These upward thrusts are numerically much smaller than their maximum possible values (1.35 - 5 kg/cm^2) and are unrelated to the pressure inside the system. In actuality, however, conditions are not ideal. If the pressure in the system rises during opertion, the electrical current in the main pump will increase slightly, indicating that the load on the shaft bearing must also increase somewhat with pressure. In other words, the water film is not perfectly continuous, and a small fraction of the surface is dry and subject to friction.

If the water film covering the tiles becomes to spotty, friction wear will be severe. As a result, mechanical "braking" forces will act on the dry areas between the thrust washers of the 2,900 rpm rotor and the stationary thrust bearing tiles located beneath it. It is this braking force which is equal to the pressure acting on the system (if we neglect the initial loading conditions), and the braking force therefore varies with the pressure. Becuase the closed loop is under high pressure, the total braking force is extraordinarily large. If the dry surface area is equal to 1 cm^2 and the loop pressure if 50 kg/cm^2, then a force of 50 kg will press the tiles tightly against the thrust washers and brake the rotor; if the loop pressure is 140 kg/cm^2 and the dry area is 1 cm^2 then a total braking force of 140 kg will act on the tiles. Therefore, the total pressure braking the rotor rises with the pressure in the system and with the area of the dry regions. As these increase, the circulation becomes impaired and the shaft bearings are damaged. This kind of damage can be detected easily by examining the electrical current passing through the main pump. As the friction increases, the pump current rises continuously as the pressure and/or dry area increases. Since the friction on the dry portions of the lower thrust tiles makes them heat up and expand, the dry areas can be detected by inspecting the disassembled pump; they have the form of depressions 0.02 - 0.04 mm deep and are usually located in the central portion. Friction continued to occur even after some of the six tiles had been worn down by as much as 0.04 - 0.15 mm (measured using a gage). If every other tile (3 tiles in all) is deliberately adjusted downward, we find that some wear still occurs in the adjusted tiles. These findings are all a consequence of frictional braking. On several occasions, when the tiles were particularly smooth and adhered very strongly to the thrust washers, the pressure was so great that the pump would not start and remained locked until the pressure was reduced to approximately 20 kg/cm^2. Severe wear of the graphite tiles could be detected by pouring water into the top of the pump; if the water emerged black then it was time to repair the main pump.

We made several dozen unsuccessful attempts at repairs and searched for ways to modify the shaft bearings. We reasoned that a stable film of water should form easily if the bottom thrust tiles had an eccentric support; since it is easy to polish the tiles to the required smoothness, we decided to test such a system in 1975. We therefore manually ground away some of the surface of the bottom thrust tiles in the central support structure (on the sides facing the water outlet); the amount of area removed was determined by calculating the area of the load-bearing water film. The modified pump operated reliably until 1980, when the stator housing was damaged. During this time the pump was turned on more than 100 times and operated for over 1,000 hours without a malfunction. Like the earlier repair, the one in 1980 was also successful and the pump has been operating normally ever since.

We may summarize our experience as follows:

1. Repairing the Pump

1) The dynamic balance of the rotor should be carefully adjusted as follows if one wishes to be successful the first time (no further adjustments required). Using the thimble hole as a fulcrum, polish the shaft and align the axle so that the curvature is less than 0.06 mm. The ends of the thrust washers must be smooth and should have less than 0.03 mm clearance from the cylindrical shaft. Themain propeller must be statically balanced to within 5 grams (this is done at the factory). Dynamic balancing should be carried out using a belt transmission balancer of appropriate size; the dynamic balancer should rotate faster than 800 rpm. Sliding bearing tiles should be used and lubricated continuously with oil when the system is turned on in order to prevent axial skipping. When adjusting the dynamic balance of the thrust washers and the rotor with its auxiliary propeller, one should remove excess weight from the rotor guard ring until the imbalance is less than 5 g•cm. The dynamic balance of the rotor with its main propeller should then be adjusted by removing excess weight from the latter until the imbalance is less than 5 g•cm.

2) Use guide bearings with appropriate, carefully selected clearances.

3) Carefully grind and adjust the lower thrust bearing assembly with its eccentric support tiles (as in the 1980 repairs described above).

If the canned pump is used correctly, only periodic maintenance and replacement of the shaft bearing will be required (usually, it is the lower thrust bearing tiles that will need to be replaced).

2. Operating the Pump

1) Start the pump up with the low-pressure valve open.

2) After the pump has been started, immediately increase the discharge to the rated level.

3) Monitor the electrical current in the water pump to see how the lower thrust bearings are operating. The current should remain within normal limits during turn-on and operation; as the water in the closed loops heats up, the electrical current should drop slightly; as the pressure in the system rises, the current should not increase to abnormal levels. Under abnormal operating conditions, the electrical current oscillates widely and can jump by as much as 10 percent without dropping, which indicates that the shaft bearings are not operating stably and that the dry surface area is increasing. This can continue until the wear is so severe that the pump must be stopped and repaired.

The workers principally involved in repairing the pump include Ye Shurong [0673 2885 2837], Tian Quanlai [3944 0356 0171], Luo Gongxin [5012 0364 0207], Xu Nong [6079 6593], Zou Xinyin [6760 1800 6892], Ling Guoxing [0407 0948 5281], Luo Mingfan [7482 6900 5400], Li Yongjia [2621 3057 0857], and Mei Yanshu [5019 1693 6615]. To all of them the author expresses his deep thanks.

12617
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BRIEFS

AMERICAN COMPANY BLASTING SEMINAR--Beijing, 3 Jul (XINHUA)--A 3-day seminar on blasting technology, given by the U.S. company, Ensign-Bicksord, opened here today. It is being sponsored by the China International Trust and Investment Corporation, and includes slides and films on the latest blasting technology. Today it was attended by more than 150 officials, engineers and technicians from factories, mines and enterprises under the Ministries of Coal, Chemical, Petroleum and Metallurgical Industries, and the General Nonferrous Metal Corporation. [Text] [OW031954 Beijing XINHUA in English 1634 GMT 3 Jul 84]

BALLOONS FOR SCIENTIFIC OBSERVATION--Beijing, June 19 (XINHUA)--China now has a series of 10,000-cubic-meter-plus altitude balloons for scientific observations. They are for use in space astronomy, atmospheric physics, space physics, remote sensing, environmental research, space chemistry and space biology. Experiments started in 1979. There have been 41 flights, up to a height of 38.1 kilometers. The biggest balloon was 50,000 cubic meters and carried 250 kilograms. An average of 10 balloons go up every year. The system was created by the Academy of Sciences' Institutes of Atmospheric Physics and High Energy Physics, the Guangzhou Electronics Institute and the Shanghai Observatory. [Text] [OW190506 Beijing XINHUA in English 0233 GMT 19 Jun 84 OW]

CSO: 4010/103

CENTER FOR CHINESE MEDICINE OPENS IN HONG KONG

OW132136 Beijing XINHUA in English 1515 GMT 13 Jun 84

[Text] Hong Kong, 13 Jun (XINHUA)--A Chinese medicinal material research center was inaugurated in the Chinese University of Hong Kong today.

In his opening address, Dr H.M. Chang, director of the center, listed the following as his center's major research projects:

--A Chinese medicines computerized database for storing clinical reports and scientific papers on Chinese medicines translated into English. Its link-up with Western databases has been established to help foreign medical scientists study Chinese medicines.

--Authentication of medicinal herbs. The center will put data on the composition of traditional Chinese medicine into computers for comparative studies and the standardization of herbal medicines.

--Research in contraceptives.

--Research projects on ginseng and herbs for treating liver and cardiovascular diseases.

Dr Chang said his research projects would focus on certain carefully selected Chinese medicines which had strong evidence of clinical efficacy for certain diseases, on which there were no effective or safe Western alternatives. He said his center expected to find new clues and new medicines to fill in the blanks in Western medicine.

A 3-day international symposium on Chinese medicines sponsored by the center opened yesterday. More than 100 scholars from many parts of the world are attending.

CSO: 4010/99

BRIEFS

BEIJING BIOTECHNOLOGY COURSE--Beijing, 18 Jun (XINHUA)--An advanced course in biotechnology given by scientists from the United States began at Beijing's science hall today. Sponsored jointly by the China national center for biotechnology development under the State Science and Technology Commission and the division of biological sciences of the Chinese Academy of Sciences, the course will last 3 weeks. Eight U.S. experts including Professor Ray Wu of Cornell University's section of biochemistry, molecular and cell biology is among the lecturers. Subjects include genetic engineering, cell biology, enzymology and fermentation. About 150 students from 90 units throughout the country are enrolled in the course. They are mainly experienced engineers, lecturers, research assistants and postgraduates studying for doctor's or master's degrees. [Text] [OW180951 Beijing XINHUA in English 0901 GMT 18 Jun 84]

CSO: 4010/99

Industrial Hygiene

AUTHOR: QU Gui'e [0575 2710 5501]

ORG: Beijing Industrial Sanitation and Occupation Disease Research Institute

TITLE: "National Investigation and Study of Occupational Poisoning and Etiological Analysis of Lead, Benzene, Mercury, Organophosporus Insecticides and Trinitrotoluene"

SOURCE: Tianjin ZHONGHUA LAODONG WEISHENG ZHIYEBING ZAZHI [CHINESE JOURNAL OF INDUSTRIAL HYGIENE AND OCCUPATIONAL DISEASES] in Chinese No 1, 25 Feb 84 pp 25-30

ABSTRACT: Participants of the study included about 13,000 sanitation personnel of all provinces, municipalities, autonomous regions, as well as the Ministries of Railways, Petroleum Industry, Chemical Industry, (and the former) Second, Third, Fourth, Fifth, Sixth and Seventh Ministries of Machine Building. Workers subjected to investigation and study were county-level-and-above state- and collective-owned factory and mining enterprises throughout China. All persons having contact with lead, benzene, mercury, organophosphorus insecticides and trinitrotoluene were subjects of study. The detailed investigative data are listed in six tables as follows:

Table 1. Operational Environment Toxic Concentration and Morbidity Rate (Due to Intoxication) of Five Toxic Substances Throughout China.

Name of Toxic Substance		Number of Sites Examined*	Acceptable Rate (percent) of Examining Locations	Toxic Concentration (mg/m^3) in Atmosphere		Morbidity Rate (percent) due to Intoxication
				Mean	State Sanitation Standard	
Lead	Lead smoke			0.681	0.03	
	Lead dust	36,974	40.40	2.221	0.05	1.69
Benzene		50,255	64.60	18.1***	40.0	0.51

Mercury	Metallic mercury	8,174	52.67	0.061	0.01	2.47
	Mercury chloride	398	71.86	0.081	0.10	1.27
	Total	8,750**	53.56			2.37**
Organo-phospho-rus insec-ticide	P-phosphorus sulfides	288	61.81	0.207	0.05	2.38
	Didiwei brand	189	32.80	1.204	0.30	8.45
	Dibaichong brand	140	33.57	3.669	1.00	3.47
	Luoguo brand	90	82.22	1.036	1.00	1.49
	Mala brand phosphorus sulfides	60	76.67	0.795	2.00	0.13
	Total	910**	50.22			3.17**
Trinitrotoluene		2,119	43.60	11.97	1.00	3.78
Grand total		99,027	54.01			1.25

Remark: *An average of 1.9 samples for each examining location
**Including mercury compounds and organophosphorus insecticides lacking sanitation standards at present
***Median data, of which 23.9 percent of samples without examining results

Table 2. General Distribution Through China of Occupational Poisoning of Five Toxins.

Name of Toxic Agent	Provinces With Most Operational Workers	Provinces and Municipalities With the Highest Number of Workers Poisoned	Highest Morbidity Rate due to Intoxication: Provinces and Municipalities, Trades and Work Categories
Lead	Sichuan Hunan Liaoning	Yunnan Liaoning Guizhou	Guizhou: smelting, teeming, fusion-refining Yunnan: storage battery, flour milling, coating-baking
Benzene	Liaoning Jiangsu Sichuan	Jiangsu Zhejiang	Zhejiang: shoe-making, rubberizing Jiangsu
Mercury	Sichuan Guizhou Liaoning	Guizhou Liaoning	Guizhou: chlorine-alkalies, chemical reactor operators Yunnan: smelting, baking, mercury instruments and meters, mercury refining and filling, manufacture: isothermal process
Organophos-phorus insecticide	Hunan Shandong	Tianjin Jiangsu	Yunnan: Didiwei brand Tianjin: Soviet chemical #203, packaging
Trinitroto-luene	Sichuan Heilongjiang	Heilongjiang Inner Mongolia	Railways, coal, pulverizing; Inner Mongolia: manufacture, drug screening

Table 3. Distribution of Morbidity Rates of Occupational Poisoning (With Five Toxic Substances) in Trades Throughout China.

Lead	Trade	Smelting	Storage Battery	Chemical Industry	Mining	Lead-containing Paints	Shipbuilding and Repair	Machine Building
	Poisoning Rate (percent)	7.67	3.66	2.70	2.38	2.00	0.84	0.58
Lead	Trade	Printing	Plastics	Others	Pharmaceutical	Electric Equipment	Glass, Instruments, and Meters; Spinning and Weaving	
	Poisoning Rate (percent)	0.49	0.49	0.36	0.34	0.22	0.2	
Benzene	Trade	Shoemaking	Storage and Transportation	Pharmaceutical	Paint Manufacture	Chemical Industry	Paint	Insulation
	Poisoning Rate (percent)	1.25	0.80	0.62	0.54	0.44	0.41	0.41
Benzene	Trade	Rubber	Others	Spray-paint	Printing	Distillation		
	Poisoning Rate (percent)	0.40	0.40	0.39	0.30	0.17		
Mercury	Trade	Chlorine-alkalies	Smelting	Manufacture of Mercury Instruments and Meters	Amalgam Smelting	Electric Equipment	Pharmaceutical	
	Poisoning Rate (percent)	12.22	9.80	9.00	6.77	2.65	2.04	
Mercury	Trade	Oral Surgery and Dentistry	Application of Mercury Instruments and Meters	Laboratory	Weighing and Measuring Instruments	Mercury Mining	Others	
	Poisoning Rate (percent)	0.68	0.61	0.40	6.12	3.10	0.00	

Table 3. [Continued]

Trinitrotoluene	Trade	Coal	Manufacture	Chemical Industry	Machinery	Others	Mining
	Poisoning Rate (percent)	6.20	4.57	3.24	1.33	1.03	0.84
Organophosphorus Insecticide	Trade	Didiwei	Soviet Chemical #203	Dibaichong	Other Varieties and Brands	P-phosphorus Sulfides	Luoguo
	Poisoning Rate (percent)	8.45	8.09	3.47	2.90	2.38	1.49

Table 4. Relationship Between Job Seniority and Positive Detection Rates of Intoxication, Cataract, and Hepatomegaly Due to Trinitrotoluene.

Job Seniority (Years)	Intoxication Rate (Percent)*	Positive Rate (percent) of Cataract**	Positive Rate (percent) of Hepatomegaly**
-1	0.28	0.00	0.73
1-	1.89	8.86	19.62
5-	6.93	24.17	35.83
10-	9.04	78.57	41.27
15-	21.55	83.65	60.46

Remark: *Total of 9375 persons: gamma poisoning 0.9548, and gamma hepatomegaly 0.9734
**Total of 804 persons: gamma cataract 0.9636

Table 5. Revised Data of Allowable Concentrations of Mercury Vapor and Mercury Chloride in Shop Air.

Toxic Substance	Source of Data	Mercury Concentration (micrograms per cubic meter)	Location Qualified Rate (percent)	Mercury Absorption Rate (percent)	Mercury Intoxication Rate (percent)
Mercury vapor	Results of national investigation	<10.0	81.6	0.72	0.00
	Results of special topic investigation	0.4-7.4*	91.4	0.95	0.00
	Regression analysis of single factor	10.00	--	<1.0	<0.10
	Regression analysis of multiple factors	10.0** 15.0***	80.0	0.42	0.13
Mercury chloride	Results of national investigation	10.0-20.0	95.7****	2.50	0.74
	Regression analysis of single factor	20.0	--	2.30	0.25

Remark: *TWA concentration; **Mean of less than 50-fold the norm; ***Overall average; ****Calculated on basis of sanitation standard at 0.1 mg/m^3.

Table 6. Job Seniority and Symptoms of Operation Workers, as Well as ChE Activity Positive Correlation Rate (Percent).

Job seniority (years)	-1	1-	5-	9-	Total
Salivation	9.6	8.7	16.5	20.8	13.3
Perspiration	18.2	28.5	26.8	28.2	25.9
Numbness of limbs	11.4	16.0	17.7	26.1	17.0
Blurring	7.0	14.7	16.4	31.4	16.0
Trembling of muscle fasciculus	8.9	13.4	15.5	32.2	15.7
Less than 60 percent ChE activity in whole blood	28.5	24.6	21.1	16.3	22.5

Remark: 1903 cases for Guangdong, Henan, Liaoning and Jiangsu (967 cases) provinces.

From the above-mentioned statistics and analysis of a wealth of data, the distribution characteristics, severity of intoxication, and causes of damage are presented for the five toxic substances in various areas, various departments, various trades, and various work categories throughout China. Analysis was made on relations among symptoms, body signs, job seniority, disease infection, dosages, and reactions. Seven figures show frequencies of benzene concentration, mercury vapor concentration, morbidity rates of lead, mercury (including lead smoke and dust, mercury vapor, and mercury chloride) and benzene.

The author represents (in compiling the study) the National Investigative Cooperative Group of Five Occupational Intoxications Throughout China; the group consists of the Beijing Industrial Sanitation and Occupation Disease Research Institute (for examining mercury poisoning), Sanitation Research Institute of China Preventive Medical Center (for benzene), Shanghai Municipal Sanitation and Epidemic Prevention Station and Shanghai Municipal Labor Research Institute (for lead), Liaoning Provincial Labor Sanitation Research Institute (for trinitrotoluene), as well as the Jiangsu Provincial Sanitation and Epidemic Prevention Station, and Zhenjiang City Sanitation and Epidemic Prevention Station (for organophosphorus insecticides).

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- END -